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Epilogue — Ways to Higher Reliability

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Abstract

This last chapter summarizes the means and recommendations for reliability increasing, which are suitable for design and operation.

Keywords: Reliability, materials, design, control, standards, maintenance, computers, measurements, diagnostics, standards, failure analysis

Many current products are much more reliable than in the past, and such trend should continue. This book summarized the methods that contribute to higher reliability. The first part (Chapters 1 to 10) explained the basic terms and methods, whereas the second part (Chapters 11 to 22) explained more advanced tools for reliability evaluation and optimization. This epilogue summarizes the means that have enabled growth of reliability and gives a brief list of recommendations for reliability increasing.

1. Experience from failures and accidents

All big accidents of aircrafts, ships, big structures, or chemical plants have been thoroughly investigated. Intensive attention has also been devoted to the frequent failures. The analysis of causes and time course of failures contributed to the improvement of the pertinent objects or constructions, to the improvement of manufacturing and building processes, and to the creation of various standards and procedures for increasing reliability and safety.

2. Reliability theory and statistical methods

The basic concepts and quantities for reliability characterization and measurement have been defined. Gradually, the main kinds of failures and their causes were identified and the

characteristic course of failure rate during the life of various objects (bathtub curve) was explained. Statistical analysis enables a better understanding and prediction of failures. The theory of probability has led to the measures for increasing reliability (e.g. the use of redundancy or the optimization of reliability of complex systems by allocating various reliabilities to the individual components). It also enables one to formulate reasonably reliable conclusions from limited information (e.g. minimum strength of a material or statistical acceptance). However, efficient methods for reliability increasing have also been developed, which do not work with probability, such as failure modes and effects analysis (FMEA).

3. Better materials, better components, and better technologies

Due to systematic research, many new materials have been developed since World War II, with outstanding properties (e.g. plastics, such as Teflon, carbon fibers, and synthetic diamond). Also, various methods of surface treatment, which increase the resistance to corrosion, high temperatures or wear (e.g. hard TiN layers on machine tools), or strength (e.g. glass strengthening by ion exchange in the surface layer). A great variety of components are available on the market. The manufacturers of various machines, appliances, and other products can buy components tailored for particular purposes and thus bring their products to perfection. Also, high-precision tools and technologies exist, which enable a better achievement of the demanded parameters of components or products.

4. Better knowledge in mechanics, materials science, and other branches

During the last 50 years, various branches of engineering sciences have made significant progress (e.g. strength of materials, fatigue, fracture mechanics, dynamics, heat transfer, and flow of liquids and gases as well as control). In design and dimensioning, one can use better models for the response of structures and appliances to operation loads. Today, a much better knowledge of materials and the causes and time course of their deterioration and failure also exists.

5. Possibility to analyze, simulate, and test the objects via computer models

The improvement thanks to computers is enormous. Computers can quickly process a huge amount of information. In the past, stresses and deformations could be analyzed only in components of simple shapes and loads, and the results were often only approximate. Very important at those times thus was the testing of physical models and actual constructions, which is cumbersome and expensive. Today, computers allow the analysis and solution of very complex problems. For example, the programs for finite-element analysis can relatively and accurately determine the stresses in complicated bodies and reveal their critical parts. As

early as in the design stage (which is crucial for reliability), it is possible to reveal the behavior under many load variants and conditions, including extreme ones. Unsuitable solutions can thus be excluded in advance. This facilitates the finding of the optimum shape or configuration, especially if computer programs for optimization are used. All this reduces the necessary extent of tests of prototypes (which are, nevertheless, still important). Computers also allow one to store and process information from the operation, which can be used for the optimization of maintenance and gradual improvements of the object.

6. Obtaining reliable design data by measurements and tests

The properties of materials or standard components can be obtained from material data sheets or manufacturers' catalogues. If they are missing, or in very demanding cases, they are gained via special tests. The important parts or prototypes are tested during the development. Overload tests done before putting the component or object into service can reveal weak pieces. Examples are load tests of bridges, overpressure tests for pressure vessels, tests of rotating parts under significantly higher velocities, and high voltage tests of electrical components and appliances. Special kinds are proof tests, in which all "weak" parts with unacceptably large defects are destroyed by controlled overloading.

7. Better techniques for the measurement of various quantities and for control; the use of diagnostics and design of intelligent devices

There has been a great improvement in measuring technologies, sensors, and devices for the analysis and processing of various quantities and signals (e.g. vibration diagnostics). All these are significantly enhanced by computers. Today, it is possible to measure gradual changes and deterioration of a component or machine and the changes of the operating conditions. In this way, the appliance can be switched off and repaired before a serious failure happens. Many production processes are 100% monitored. For example, in the production line for glass bottles (with the rate one bottle per second), all important parameters are measured at every bottle and also their changes with time. This, together with the identification of individual moulds, makes possible an early intervention targeted only at the problematic mould. The evolution proceeds towards smart devices with self-control. Two examples of intelligent elements from everyday life can be named: indication of unfastened seatbelts in a car and automatic dynamic balancing of the content in a home washing machine before spinning.

8. Codes and mandatory procedures to ensure reliability and safety

Experience, gathered continuously for a long time, has been incorporated into standards and regulations. These include a variety of proven procedures and practices that guarantee a

universally acceptable level of reliability; see, for example, the codes for the design of steel structures or standards for production and acceptance control. Codes also represent certain etalons in disputes arising due to malfunction or accident.

9. Organizational measures, consistent control of processes, and operation

Even the best technical ideas, solutions, and regulations are useless if their application is not ensured. In complex processes, this must be achieved organizationally. Where necessary, checks must be done consistently at the input, during the process, and at the output. It is reasonable to seek ways for the elimination of human errors (e.g. by replacing physical or mental work by machines and computers). If this is not possible, emphasis must be put on personal responsibility. For example, in manual welding or inspection of welds, every qualified worker has his personal stamp to confirm that it was he who has done the operation.

10. Better approaches to maintenance

From the originally used maintenance after failure, the development went over preventive maintenance, done in fixed intervals, to on-condition maintenance, which strongly uses technical diagnostics and decides with respect to the actual condition. The newest trend is reliability centered maintenance, which reduces the pertinent costs by the elimination of all unnecessary maintenance works as revealed by a thorough analysis.

11. Competition and legal responsibility for defects and failures

In economic systems where supply exceeds demand and a possibility of choice exists, emphasis is put on reliability. Free market and competition make permanent pressure on manufacturers to improve their products. If several firms can make certain products at a similar price, the firm, whose products are more reliable, will win, as the losses due to the failures of its products will be lower. The pressure toward increasing reliability is also supported by legislation, with legal responsibility for any defect, failure, or damage caused by them.

12. Recommendations for reliable design and operation

1. Use experience from failures and accidents of similar objects in the past.
2. Obtain all demands on service life and reliability (dependability).
3. Obtain the relevant information on the conditions of operation and other demands.

4. Obtain all relevant information on the loads acting during operation and in extraordinary or extreme situations (e.g. during building and due to climatic events).
5. Select proper materials and components with guaranteed quality and reliability; use well-proven manufacturing technologies.
6. Use reliable data on materials and components. Obtain them by testing if they are missing.
7. Use reliability methods, including probability and statistics.
8. Use standards and well-proven procedures for reliability and safety ensuring.
9. Propose the optimum arrangement of the object.
10. Use redundancy for reliability increasing. Optimize reliability allocation to individual parts and components.
11. Use the failure modes and effects analysis (FMEA) and the fault tree analysis.
12. Use the robust design approach. Make analysis of the sensitivity to variations of input quantities. Use design of experiments (DOE). Set appropriate tolerances.
13. Use proper dimensioning for the assumed loads and demanded load response.
14. Use up-to-date methods from mechanics and other relevant branches.
15. Use computer-optimized design. Use simulation and study the response in common and extreme situations. Do it as early as in the design stage.
16. Diminish the influence of human factor. Use "intelligent" appliances.
17. Control the purchased parts and operations in manufacture and building.
18. Monitor all important parameters in operation to predict the best time for renewal.
19. Use diagnostics.
20. Prescribe and use suitable system of maintenance and repairs.

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